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CONDITIONS OF PROACTIVE INHIBITION IN FREE RECALL[1]

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Proactive inhibition (PI) was investigated under conditions of multiple-trial free recall. Control *S*s learned one 20-item list, while experimental *S*s learned two. Retention was tested either 15 min. or 48 hr. after acquisition. The recall procedure varied for the experimental conditions: *S*s were instructed to recall the second list only (Single List), to recall the second list with the knowledge that a first-list recall would follow (Successive), or to recall both lists (MMFR). PI was present at the two retention intervals. The amount of PI varied among the experimental conditions with the Single-List condition showing superior second-list recall. Output interference at the time of recall appeared to determine the magnitude of PI.

This study investigates proactive inhibition (PI) under conditions of multiple-trial free recall (MTFR). The question of theoretical interest concerns the mechanisms of interference that influence response recall per se. Classical interpretations of PI have only a limited bearing on this question because they have focused primarily on sources of associative loss. Thus, within the framework of two-factor theory (Melton & Irwin, 1940; Melton & von Lackum, 1941), PI is attributed entirely to competition between alternative responses to specific stimuli. In light of recent evidence, the amount of interference from prior lists must also be assumed to depend critically on the degree of list differentiation (Underwood & Ekstrand, 1966, 1967, 1968). Unlearning, which is a major determinant of retroactive inhibition, obviously does not apply to the most recently acquired task. Of these sources of interference, the only one that may be expected to contribute to PI in the retention of free recall lists is loss of list differentiation.

There is evidence that list differentiation does, indeed, decline as a function of time when original learning is by the method of MTFR (Abra, 1970; Winograd, 1968). The question arises whether this factor is sufficient to account for whatever proactive losses are observed under this condition of practice. If it is, then PI should be eliminated when correct performance on the test of retention is not contingent on list differentiation. This requirement is met when the equivalent of an MMFR test is used and *S*s are instructed to recall both the prior and the terminal lists in any order they wish. If PI is still found under these circumstances, then the sources of interference must be sought outside list differentiation in the conventional sense. It would then become plausible to infer that the acquisition of multiple lists enhances output interference at the time of recall.

Output interference refers to the detrimental effects of recall on further recall (cf. Tulving & Arbuckle, 1963, 1966). That is, given the acquisition of Items *a* and *b*, the recall of *a* is an interpolated activity which may serve to reduce the probability that *b* can be reproduced. Such interference should occur only if *a* and *b* are not associatively related or part of the same higher order grouping. The argument can be readily extended to the recall of two (or more) lists. Recall of items from List A will militate against the reproduction of items from List B because a change in response set (cf. Postman, Stark, & Fraser, 1968) or a shift from one set of retrieval cues to another is required as *S* moves from one group of words to the other. It is apparent that the opportunities for output interference should become greater as the number of lists learned in the same experimental context increases.

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Output interference as explicated here should be distinguished clearly from failures of list differentiation, although the two mechanisms are obviously not independent of each other. Failures of differentiation will be conducive to alternation between lists at the time of recall. However, such alternation may occur even when there is no uncertainty about the list membership of individual items, e.g., as a result of intertask similarities. Thus, recall of an item from List A may stimulate the reproduction of an item from List B because the two belong to the same taxonomic category or are otherwise related. The *S* may, however, be fully aware of the fact that the two words had occurred in different lists. Failures of list differentiation are therefore a sufficient, but not a necessary, condition of output interference at the time of recall.

The shifts in response set which result in output interference may be implicit or explicit. They will be largely implicit when *S* is instructed to limit his recall to one list, e.g., the most recently learned one. Presumably, intrusions from the alternative list will frequently be recognized as such and withheld. Explicit alternations become very likely when recall of both lists is requested (MMFR). The interesting implication is that an MMFR procedure, which is conventionally assumed to be immune to the effects of response competition, may be more conducive to output interference than recall of the second list only. To the extent that output interference is responsible for PI in free recall, the observed amounts of interference should, therefore, be greater in the former than in the latter case.

With these considerations in mind, PI in the present experiment was measured both by an MMFR test and by a conventional test in which *S* was instructed to recall the second list only. In addition, a variant on the latter condition was used in which *S* was informed that recall of the second list would be followed by a test on the first list. The purpose of that manipulation was to maximize implicit changes in response set since *S* would presumably be led to rehearse at least some first-list items while recalling the second list.

Method

Design.—The design comprised two control groups and six experimental groups. The control groups learned a single list of words and were given a test of retention either 15 min. or 48 hr. after the end of acquisition. The six experimental treatments represented the factorial combination of the two retention intervals and three methods of testing second-list recall. The three testing procedures were Single-List Recall, Successive Recall, and MMFR.

In the Single-List condition, *S*s were instructed at the beginning of the retention test to recall the second list only. The same instructions were given to the Successive Recall groups, with the additional statement they would later be tested on the first list as well. Actually, a test on the first list was given to both the Single-List and the Successive groups in the second phase of the recall session. In the MMFR condition, *S*s were requested to recall the items from both lists in any order they wished.

Materials.—The learning materials were nine 20-word lists. Each list contained 10 one-syllable nouns and 10 two-syllable nouns. Half of the words in each list had ratings of A and the other half ratings of AA in the Thorndike-Lorge frequency count. Each of the nine lists was used as the first and as the second task equally often.

Acquisition.—The lists were learned by the study-test method. On study trials, the items were exposed in the window of a memory drum at a 1.5-sec. rate. A different random order of presentation was used on each trial. The successive orders were subject to the restrictions that no item appear in the same serial position more than once and that there be no duplication of sequences of two or more items.

Each study trial was followed by a 60-sec. oral test of recall, with *S* instructed to call out the items in any order he wished. However, a 2-min. written test of recall was given after the last study trial in order to make the terminal test directly comparable with the procedures used in measuring retention. The *S*s were informed about the testing arrangements at the beginning of the session. Under the experimental conditions, the interval between the first and the second list was approximately 3 min., 45 sec.

In order to equate the terminal level of acquisition for the control and the experimental groups, the first list was presented for four, and the second list for three, study-test cycles. On the basis of the results of a previous study investigating nonspecific transfer effects in free recall with the same materials (Postman, Burns, & Hasher, 1970), it was expected that this adjustment of trials would yield a terminal level of performance on both lists of approximately 16/20.

Test of retention.—The tests of retention were administered either 15 min. or 48 hr. after the end of second-list learning. For *S*s tested after 15 min.,

TABLE 1

MEAN NUMBERS OF CORRECT RESPONSES ON TERMINAL TRIAL OF TEST-LIST LEARNING

Cond.	Retention interval	
	15 min.	48 hr.
Control	16.61	16.44
Single List	16.17	15.22
Successive	14.39	17.06
MMFR	15.61	16.17

the retention interval was filled with work on arithmetic problems; *S*s tested after 48 hr. performed the same task for 15 min. after the end of second-list learning and were then dismissed.

The retention tests were written, with *S*s once more instructed to reproduce a given set of items in any order. The sequence of events in the retention session will be detailed separately for each of the conditions.

1. Control. There was an initial 2-min. test, followed by a further 2-min. period during which *S*s had an opportunity to write down any additional words that occurred to them.

2. Single-List and Successive Recall. The procedure comprised three phases. Initially, *S*s were given 2 min. to recall the second list. A 2-min. test on the first list followed immediately thereafter. During a final 2-min. period, *S*s were allowed to write down additional words from either list.

3. MMFR. The *S*s were given 4 min. to recall the items from both the first and second lists. Again, there was a terminal 2-min. period for recording additional words.[3]

Following the recall period, an unpaced test of list differentiation was administered to all experimental groups. On the test sheet, the words from both lists were listed together in alphabetical order. The *S*s were instructed to identify the list membership of each word by writing the number 1 or 2 next to it; they were required to respond to each item, guessing if necessary.

Subjects.—There were 18 *S*s in each of the eight groups. The *S*s were undergraduate students at the University of California who were naïve to free recall learning. They were assigned to conditions in blocks of 8, with 1 *S* from each condition per block.

[3] During the terminal 2-min. period, *S*s had their final recall protocol before them. Consequently, *S*s in the MMFR condition could view the words they had recalled from both lists; those in the other two conditions had access to only their first-list items. Thus, the arrangement may have favored the MMFR groups with respect to recall of additional items from the second list. The existing evidence on cueing effects (Slamecka, 1968) suggests, however, that the bias, if present at all, was negligible.

RESULTS

First-list learning.—The mean number of correct responses on the final test trial of first-list learning was 16.23, with the means of individual groups ranging from 15.67 to 16.83. There were no reliable differences among the groups, which may, therefore, be considered comparable in learning ability.

Second-list learning.—Table 1 shows the mean score of each experimental group on the final test trial of second-list learning. The means of the control groups are for the final test on the first and only list learned by these *S*s. The adjustment in the number of trials served to equate the terminal level of acquisition of the experimental and the control groups. The overall means were 15.77 and 16.52, respectively.

There was some variation in the scores of the experimental groups. As it happened, the lowest and the highest values were obtained by the Successive Recall groups tested after 15 min. and 48 hr., respectively. Consequently, a 4×2 analysis of variance of the terminal second-list scores yielded a significant Condition $\times$ Retention Interval interaction ($p < .01$). Neither of the main effects in this analysis was significant. In view of the sampling fluctuations in second-list performance, the statistical analyses of the retention measures will be based on the differences between the terminal level of acquisition and the test of recall.

Second-list recall.—The mean measures of second-list recall are summarized in Table 2. Both the amounts recalled and the loss scores (differences between final trial of acquisition and test of retention) are shown. The table is divided into two sections: (*a*) the results of the initial test phase and (*b*) the cumulative scores attained during the entire test period. The initial test phase was 2 min. long under the Control, Single-List, and Successive Recall conditions. The comparable scores of the MMFR groups were obtained in the 4-min. test period during which *S*s recalled both lists. The cumulative scores were based on the numbers of test-list items reproduced at any time during the entire recall procedure.

In the initial test phase, the retention losses were greater under the experimental than under the control conditions. This pattern was present on both the 15-min. and the 48-hr. tests. The difference between the control and the combined experimental conditions was significant ($p < .01$) but did not interact reliably with retention interval, Fs (1, 136) = 17.00 and 2.16, respectively. Thus, prior learning served to depress test-list recall, but the proactive effects did not increase significantly over time. This conclusion remained unchanged when each experimental condition was compared separately with the control condition: In all cases, there was a significant main effect of treatment but no reliable interaction with the length of the retention interval.

The differences among the experimental conditions will be considered next. An orthogonal comparison showed that Single-List Recall resulted in smaller losses than did the Successive Recall and MMFR treatments ($p < .05$). In the case of the latter, however, this difference was clearly apparent only on the delayed test. The performance of the Successive Recall groups was poorer than that of the MMFR groups ($p < .05$). Appropriate tests of interaction indicated that there were no reliable changes in these differences over time.

The cumulative scores reflected gains for all groups; i.e, in each case, *S*s succeeded in reproducing additional second-list items after the end of the initial recall period. Relative to the pattern of scores in the initial test phase, there was a convergence of the control and Single-List groups on the one hand and the Successive and MMFR groups on the other. Both the latter two fell reliably ($p < .01$) below the control treatment, whereas the Single-List condition did not. An orthogonal comparison showed once again smaller losses under the Single-List than under the other two treatments ($p < .02$). The Successive and MMFR conditions no longer differed significantly. As before, there were no reliable interactions with retention interval.

In general, then, the two procedures that served to focus *S*s' attention on the alternative list depressed test-list recall. The early inferiority of the Successive groups suggests that anticipation of a further test was a sustained source of interference throughout second-list recall; the detrimental effects built up more gradually under the MMFR treatment since *S*s had the option of reproducing a string of items from one list before shifting to the other. In fact, some evidence will be reported below suggesting that on the immediate MMFR test *S*s tended to produce second-list items early in their recall. On the delayed MMFR test, however, this output bias had dissipated, so that there was greater alternation between lists. The apparent temporal trend in the MMFR scores becomes understandable on this basis.

TABLE 2

MEAN SECOND-LIST SCORES ON TESTS OF RETENTION

Cond.	Retention interval 15 min. Recall	15 min. Loss	48 hr. Recall	48 hr. Loss
Initial test phase				
Control	15.89	.78	11.22	5.22
Single List	14.39	1.78	8.33	6.89
Successive	11.61	2.78	7.45	9.61
MMFR	13.72	1.89	8.22	7.94
Cumulative score				
Control	16.56	.11	11.78	4.67
Single List	15.28	.89	10.06	5.17
Successive	13.28	1.11	9.61	7.44
MMFR	14.28	1.33	8.61	7.56

First-list recall.—The measures of first-list recall are summarized in Table 3. The distinction between the amounts recalled in the initial test phase and the cumulative scores is maintained. The former now refer to *S*s' performance during the period in which they were instructed to recall the first list; the latter are based on the number of first-list items recalled at any time during the retention test. The scores of the control as well as of the experimental groups are included in Table 3. It must be borne

TABLE 3

Mean First-List Scores on Tests of Retention

Cond.	Retention interval			
	15 min.		48 hr.	
	Recall	Loss	Recall	Loss
Initial test phase				
Control	15.89	.78	11.22	5.22
Single List	11.06	4.72	6.28	9.39
Successive	10.78	5.00	6.22	10.61
MMFR	12.89	3.11	8.72	8.00
Cumulative score				
Control	16.56	.11	11.78	4.67
Single List	12.67	3.11	8.39	7.28
Successive	12.67	3.11	8.39	8.44
MMFR	13.45	2.56	9.11	7.61

in mind, however, that under the experimental treatments the retention intervals were defined with respect to the end of second-list learning. When retention of the first list is considered, therefore, the intervals were longer for experimental than for control *S*s. The resulting bias in favor of the latter may be viewed as negligible in the case of the 48-hr., if not the 15-min., tests. Nevertheless, statistical analysis of the first-list loss scores will be limited to the experimental conditions.

At both retention intervals, the losses in the initial test phase were smaller for the MMFR than for the Single-List and Successive Recall groups. The apparent source of this difference is the temporal arrangement of the recall procedures. Under the MMFR condition, *S*s were engaged in recalling both lists from the beginning of the test period; under the other two conditions, recall of the second list preceded that of the first. Alternation between lists, possible under MMFR conditions, was less damaging to performance on the first list than was prior recall of the entire second list. At the same time, this same alternation diminished performance on the second list, compared to immediate recall of that list. Thus, the MMFR measures provide points of reference for the evaluation of output interference.

Analysis of variance of the first-list loss scores for the initial phase of recall yielded a significant main effect of conditions, F (2, 102) = 4.71, $p < .02$. In an orthogonal comparison of the MMFR with the Single-List and Successive Recall groups, the value of F (1, 102) was 8.40, $p < .01$. The latter two conditions did not differ reliably, $F = 1.01$. The differences among treatments did not interact with the length of the retention interval, $F < 1$. (It will be noted that the orthogonal comparison differed from that used in the analysis of second-list recall, where the Single-List condition was compared with the other two experimental conditions. In each case, the contrast was between the experimental treatment that maximized attention to the given test list from the beginning of the recall period on the one hand, and the remaining ones on the other.)

The cumulative scores obtained under the three treatments were comparable, and the differences among them were no longer significant, $F = 1.24$. The decrement produced by a prior second-list test was, therefore, transitory. In this connection, it should be noted that first-list intrusions given during the recall of the second list in the initial test phase were included in the cumulative scores.

Order of recall in MMFR.—The interpretation of the results obtained on the MMFR test hinges on the assumption that *S*s did not recall the entire second list before moving on to the first. To the extent they did in fact do so, the functional difference between the MMFR and the other two conditions would be attenuated. With this question in mind, an analysis of the order of output on the MMFR test was undertaken. The items recalled by each *S* were arranged according to their order of output, and the protocol was then divided into halves. The measure used in the analysis was the percentage of items in the first half of the protocol that came from the second list. The expected value, on the assumption of a random order of output, is equal to the percentage of second-list items in the entire protocol. The difference between the obtained and the

TABLE 5

Mean Total Recall Scores (List 1 + List 2)

Cond.	Retention interval	
	15 min.	48 hr.
Single list	27.94	18.44
Successive	25.94	18.00
MMFR	27.72	17.72

cumulative scores for the two lists. It is apparent that there were only minor variations in the total scores of the three experimental treatments. On the 48-hr. test, the scores were virtually identical. The method of testing influenced only the distribution of items between the two lists. This pattern suggests that first-list and second-list items were equally available, but that the conditions of output interference determined how many members of each set were actually reproduced during the test period.

List differentiation.—The measures of list differentiation, based on the percentages of correct identifications minus the percentages of false alarms, are presented in Table 6. With *S*s required to classify all items, the first-list and the second-list scores were, of course, the same.[4] It will be recalled that the test of differentiation was administered at the end of the recall period and thus could not reflect transitory influences on performance in the successive phases of the recall period. As the table shows, there was a substantial decline in the accuracy of list identification over time, F (1, 102) = 65.74, $p < .01$. However, none of the sources of variance associated with experimental treatment approached significance.

Discussion

The amount of PI in the retention of lists learned by MTFR depends critically on the conditions of testing. The differences among the experimental treatments support the conclusion that the magnitude of the proactive losses is determined in large measure by the degree of output interference at the time of recall. Specifically, the superiority of the Single-List groups in second-list recall, and of the MMFR groups in first-list recall, becomes understandable on this assumption.

Descriptively, output interference refers to the detrimental effects of recall on further recall. In the context of a test for PI, the source of the output interference is the implicit or explicit arousal of the responses from the prior lists. The prior list and the test list represent alternative repertoires. The reproduction of individual items from each of these repertoires is presumably contingent on different sets of retrieval cues and on the reactivation of different higher order groupings or associative networks at the time of recall. If the reproduction of items from one repertoire is interrupted by the arousal of the alternative one, the shift back to the original system may be sufficiently difficult to disturb the orderly course of retrieval. For example, *S* may not complete the recall of a particular group of items or may embark on a new associative pathway. As a result of the disruption, potentially available items may not be recovered; i.e., there may be no successful "reentry" into the original retrieval sequence.

Such output interference can come into play whenever a grouping or associative chain is interrupted and superseded by alternative ones. The sets of items between which there is interference may come from the same list or from different lists learned in succession. Under conditions of Single-List Recall in this experiment, output interference would be expected to operate between items in the first and second lists, where there undoubtedly were similarities between attributes—semantic, associative, orthographic, and so on (cf. Underwood, 1969)—used for words in both lists.

TABLE 6

Mean List Identification Scores

Cond.	Retention interval	
	15 min.	48 hr.
Single list	78.0	34.7
Successive	68.0	36.1
MMFR	72.2	23.0

Note.—Scores are based on percentages correct minus percentages of false alarms.

[4] The *S*s did, in fact, classify all items without exception. Since the percentages correct on one list and the percentages of false alarms for the other list were complementary, the corrected differentiation scores were always identical for the two lists.

However, the degree of interference is obviously subject to manipulation: In the present study, it appears to have been enhanced substantially by the requirement to recall both lists simultaneously (MMFR) and by the announcement of an impending test on the first list (Successive Recall). These manipulations served to increase not only the effectiveness of the interference in the initial phase of the test, but also the persistence of the retention deficit during the remainder of the testing session. The differences among the conditions of testing observed here are consistent with results obtained in studies of short-term retention (Brown, 1954; Epstein, 1969, 1970). It should be noted, however, that in a previous study of PI in free recall, Shuell and Koehler (1970) failed to find a reliable difference between conditions corresponding to Single-List Recall and MMFR in the present experiment. The amounts of PI in that study were marginal at best, at least in the two-list situation. The reasons for this discrepancy in experimental findings remain to be determined.

By definition, PI increases as a function of time when the end of test-list learning is taken as the point of reference. As far as the defining characteristics of PI are concerned, however, the divergence need not be progressive. In the present experiment, the proactive losses did not increase reliably as a function of the length of the retention interval. This result is consistent with the view that the sources of interference are inherent in the test procedure when *S* is required to reproduce responses from alternative repertoires acquired in the same experimental context. There is no evidence for an irreversible loss in the availability of second-list responses: The cumulative scores of the Single-List groups did not differ significantly from those of the control groups.

A finding that warrants emphasis is the inferiority of the MMFR groups to the Single-List Recall groups in second-list performance. In the analysis of unlearning, one of the valuable properties of the MMFR test is its apparent immunity to specific response competition: Presumably, first-list responses that are momentarily blocked can still be given under this unpaced procedure. As was pointed out previously, however, there is no reason to suppose that performance on an MMFR test is equally immune to generalized response competition or response-set interference (Postman et al., 1968). The latter two concepts refer to the persistence of a set to give responses from the list learned last; they are related to output interference in the sense that the interferences assumed to reduce recall are seen as falling on an entire response repertoire rather than on individual associations. However, the defining characteristic of output interference is not the persistence of a set established during acquisition; rather, it is the degradation of recall resulting from the arousal of alternative response dispositions. The methodological point which emerges is that recall cannot be safely assumed to be higher under all circumstances in MMFR than in single-list recall. When susceptibility to output interference becomes critical and is not outweighed by other factors (e.g., freedom from specific response competition), the opposite can be true, as is the case in the present experiment.

Finally, a comment is in order on the role of list differentiation in producing PI in free recall. The occurrence of intrusions and the results of the test of list identification agreed in showing failures of list differentiation at both retention intervals. It is reasonable to suppose that performance under the Single-List and Successive Recall conditions was depressed by failures of differentiation. However, the weight of this factor in determining the amount of PI may be taken to be quite limited for two reasons: (*a*) While the level of differentiation was comparable for the three experimental treatments, the magnitude of the proactive losses was not; (*b*) in spite of the severe decline in list differentiation between 15 min. and 48 hr., there were no significant increases in PI over that interval. What appears to be the major determinant of PI in paired-associate recall thus is of only secondary importance in free recall. This conclusion is consistent with the general implication of the present findings, namely, that the mechanisms of proaction in free recall are in most essential respects different from those in associative recall.

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